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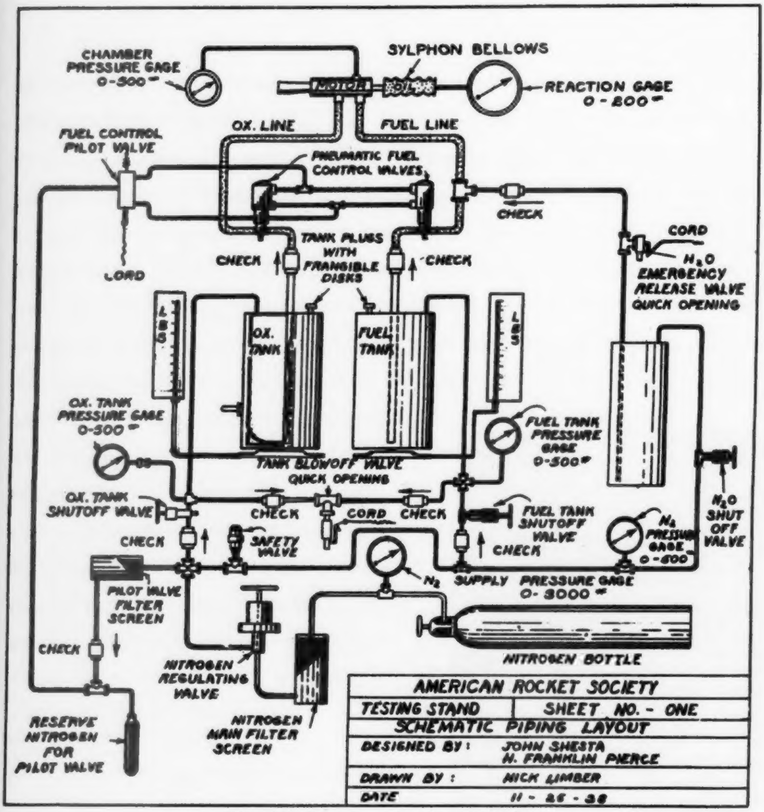


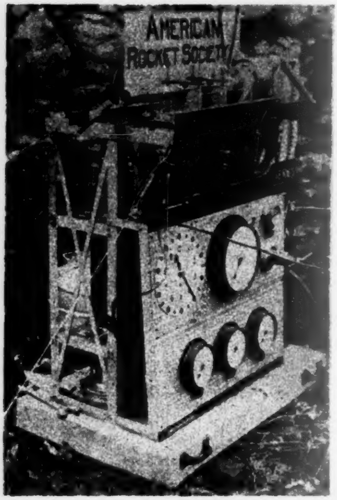
Schematic Diagram of Proving Stand #2

Report on The 1938 Rocket Motor Tests
Annapolis Motor Tests
Experimental Rocket, Model 1939....A.R.S.Bulletin

REPORT ON THE 1938 ROCKET MOTOR TESTS

Although the 1938 American Rocket Society motor tests were limited in scope because of unavoidable delays in completing Proving Stand No.2, the results obtained were most interesting and important. The performance of the stand itself was highly satisfactory and a great advance over that of previous tests, and the results of the motor trials showed that great progress has been made toward the solution of the motor problem.

Our front cover gives the schematic arrangement of the new stand. As will be seen by a comparison with the April, 1938 "ASTRONAUTICS", many refinements were introduced during the stand's construction, particularly a pneumatic system for operating the fuel and oxygen valves. These can be instantly opened or closed by nitrogen pressure controlled by a small pilot slide valve. Despite its complexity, this system proved highly convenient and reliable in actual operation. The constant-pressure nitrogen feed system and the hydraulic tank-weighing devices also proved satisfactory. The only considerable difficulty encountered with the new stand was the problem of transporting and handling it, because of its weight of some 300 pounds; but the provision of carrying handles and a special trailer for road transportation have improved matters greatly.



Proving Stand No. 2

A water-flush system has been provided to cool the motor quickly after a run.

The general construction of the stand is shown by the photograph. The three dials at the bottom indicate the chamber and

tank pressures; the large center dial reads the reaction, and to right and left of it appear the pressure regulator and the clock. The gage glasses giving the tank weights are on the right-hand panel, and the motor carriage is on top of the stand.

In use, the stand was carefully leveled and then braced with guy wires to prevent the motor thrust from upsetting it.

Commercial denatured ethyl alcohol was used as a fuel in all tests.

The first tests were run on Oct. 22, 1938, at New Rochelle, N.Y. They were of a preliminary nature, intended to test the general operation of the stand. A tubular Monel motor built by Mr. H. Franklin Pierce was used, because of its simple and solid construction. A new ignition scheme was tried, employing small pieces of powder fuse placed inside the motor and fired by the usual electric hot-wire; but this failed to work well in two attempts, apparently because of dampening of the fuse by fuel leakage. Another trial, using a wad of ignited alcohol-soaked waste placed outside the nozzle, resulted in intermittent unsteady combustion, with a momentary reaction of 40 pounds. A fourth test produced only a large alcohol flame burning in air, owing to failure of the oxygen valve to function because of frost in the spindle packing.

These defects were remedied before the next tests. A new and large cylinder was made for the oxygen valve, to overcome any sticking. A new test site (also at New Rochelle) was located which had a source of A.C. electricity close by, and accordingly the clock of the old stand was replaced by an electric one especially constructed for the purpose, having two hands one revolving once in 10 seconds and the other once in 100 seconds. Large tubular powder fuses, similar to those used in 1935, and electrically ignited, were prepared instead of the small fuse.

In the second series of experiments, on Dec. 10, 1938, three motors were tested. About 2 1/2 pounds of alcohol and 4 pounds of loxygen were used in each of the first three runs. The first motor was the

Pierce design used in the October tests, modified by the addition of a baffle-plate, ahead of the fuel and oxygen ports, intended to promote mixing. On firing, a long, diffuse, yellowish flame appeared, which burned for several seconds, giving about 90 pounds reaction. At this point one of the fuel lines burst at a joint, and the motor was shut off at once. Examination showed that the baffle plate had been broken loose by a rise in pressure behind it and had become wedged in the nozzle, causing a pressure shock which burst the fuel line.

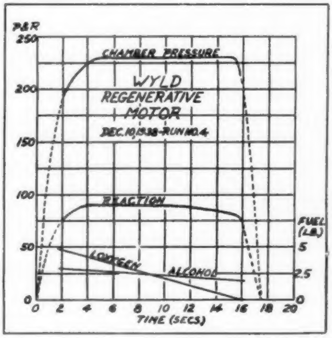
The line was repaired and a second motor mounted, the tubular regenerative one built by J.H.Wyld. When ignited, a very large, diffuse, crackling, yellow flame was produced, but no reaction, showing that the combustion had failed to work back inside the motor from the fuse. It was decided to give it a second trial after the next test, which was made on another tubular regenerative motor submitted by R.C.Truax of the Naval College at Annapolis. This motor was of steel, about 18 inches long, with a long, slender, throat-fed combustion chamber about an inch in diameter and ten inches long, feeding a nozzle about 8 inches in length, with a 3/8 inch throat and a 1-1/4 inch mouth (while the Wyld motor was 2 inches internal diameter, 6 inches chamber length, 1-1/2 inch nozzle length, 5/8 inch throat and 1 inch mouth.) These inner parts of the Truax motor were surrounded by a jacket into which the fuel was fed near the motor head, afterwards passing down the outside of the chamber and nozzle to the mouth of the latter, from which it returned through a pair of small tubes to two 1/32 inch ports near the throat. The loxygen was injected through a port in the side of the chamber about two inches from the fuel ports. A special heavy-walled fuse screwed into the head of the motor was used for ignition.

This motor fired quite well for several seconds, but the flame then became yellowish and full of sparks and a moment later the side of the motor burned out. The run was stopped and an examination made. It was found that the oxygen, besides cutting a hole through both motor walls just opposite the oxygen port, had also entirely burnt out the

nozzle, of which only a small fragment remained. Apparently alcohol vapor had formed in the jacket which could not escape through the small fuel ports, and a vapor-lock effect thus developed which caused overheating and destruction of the nozzle.

In the fourth test, the Wyld motor was again tested. All the remaining fuel, about 4 1/2 pounds of alcohol and 6 1/2 pounds of oxygen, was used. The fuses were used for ignition, along with some loose gunpowder in the nozzle, and the metering orifice provided in the alcohol line was replaced by a smaller one, to give a leaner mixture.

The run began with a large, yellow flame, which shortened into a straight, blue one after a few seconds, the reaction simultaneously rising to 90 pounds, which was steadily maintained for about 13 1/2 seconds, after which it quickly fell to zero as the loxygen gave out. Examination of the motor showed that it was in good condition except for some melting and erosion of the head and liner about an inch from the injection ports.



The test figures for the Pierce and Truax motors have not been fully analysed because of the rather erratic firing. It appears that the mixture was too rich in the case of the Pierce motor, while the Truax motor gave only 20 pounds reaction despite a chamber pressure of some 250 lb sq in. apparently because of overexpansion and shock losses in the large nozzle. The results on the Wyld motor are as follows (for the period of efficient combustion): Maximum reaction, 91 lb.; alcohol feed, 0.084 lb/sec; oxygen feed, 0.34 lb/sec; tank pressure, 250 lb/sq in; chamber pressure, 230 lb/sq in.; chamber pressure, 230 lb/sq; maximum exhaust velocity, 6870 ft/sec ; maximum thermal efficiency, about 40 %; jet energy, 310000 ft-lb/sec,

or 565 H.P. These figures represent a great advance on those obtained in former tests, and are among the highest ever recorded. The fact that they were reached without severe damage to the motor is especially encouraging and definitely proves the feasibility of the regenerative method of cooling.

The experimental committee is now preparing for another series of tests. A special recording camera is being constructed, using 35 mm. film, since it has proved difficult to read the 16 mm motion pictures accurately. Certain parts of the Wyld motor, originally of aluminum, are being replaced by Monel ones, to resist the heat better. It is hoped to obtain a 30 or 40 second run in the next tests. A special fuel preheater to supply hot fuel at the start of a run is also being built.

In conclusion, the Experimental Committee wish to thank the many members of the American Rocket Society and the Westchester Rocket Society who assisted in conducting the tests.

John Shesta

H. Franklin Pierce

James H. Wyld

ANNAPOLIS MOTOR TESTS

Report on research at the U.S. Naval Engineering Experiment Station.

by

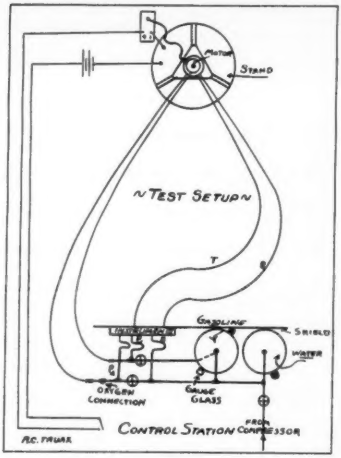
Midshipman R.C.Truax, Annapolis, Md.

The writer is happy to be able to present herewith a report of further experiments along the lines of those presented in the April 1938 Astronautics. This series of tests was conducted under the unofficial sponsorship of the U.S.Naval Engineering Experiment Station, Annapolis, Md.

The motor used was similar to that used in the December tests, but modified by substituting a refractory-lined nozzle for the previous

water-cooled one.

The test apparatus consisted of a hydraulic weighing system, gasoline tank, ignition circuit, combustion chamber, valves, piping, and the gauges necessary to measure the following quantities: supply air pressure, gasoline feed pressure, air feed pressure, gasoline consumption, and time. For safety, the apparatus was given a 300% hydrostatic test and a 1/4" steel plate was interposed between tanks and motor. The accompanying sketch indicates the general layout.



Schematic Diagram of the
Truax Test Stand

Air and gasoline under pressure were forced into the combustion flask, vaporized and thoroughly mixed. A spark ignited the mixture, and the gases of combustion passed out through a diverging nozzle. The motor fired vertically upward, and its reaction was received by a hydraulic piston which transmitted the thrust through a pressure line to the thrust gage on the instrument panel.

Following the customary practice, the thermal efficiency was defined as the kinetic energy of the jet divided by the thermal energy of the fuel, and was computed from the thrust and the mass rate of flow. Other measurements were for identification purposes.

The motor was run at constant chamber pressure for ten to forty-five seconds and the gasoline consumption and other readings were recorded during the interval (photographically, for the first five runs, and manually, for the last two.) Gasoline flow was measured by a gage glass on the tank. The fuel was assumed to burn fifteen times its weight of air, a reasonable supposition considering the sensitiveness of the mixture ratio during the tests.

Sample Calculation (Run No.1)

S	supply air	300 lb./sq in
P_a	air feed	100 "
P_f	fuel feed	100 "
P_c	ch. press.	70 "
T	thrust	6.25 lbs.
t	time	19 secs
f	fuel used	.119 lb

$$W = \frac{16f}{t} = \frac{16 \times .119}{19} = .10 \text{ lb/sec}$$

$$V = \frac{T}{m} = \frac{Tg}{w} = \frac{6.25 \times 32.2}{.10} = 2010 \text{ ft/sec}$$

Q = 1250 Btu per lb mixture

$$K.E. = 1/2mv^2 = \frac{(2010)^2}{64.4 \times 778} - 81.1 \text{ Btu/lb}$$

$$E_{th} = \frac{K.E.}{Q} = \frac{81.1}{1250} - 6.54$$

Summary of Results:

Run No.	1	2	3	4	5	6	7
S	300	300	300	300	300	400	400
P_a lb/sq in	100	110	140	160	200	---	---
P_f "	100	160	200	225	250	---	---
P_c ""	70	90	100	120	170	180	190
T lb	6	7	10.4	15	16.5	22	25
t secs	19	15	20	15	13	45	20
f lb	0.12	0.065	0.13	0.11	0.09	0.40	0.20
v ft/sec	2010	3250	3220	4260	4900	5000	5040
E_{th} %	6.5	16.8	16.6	29.0	38.0	40.0	40.3

Accuracy:

Calculations were not carried out to greater than slide rule accuracy because of the large experimental error. In the first five runs, the photographs and short time intervals combined to make gasoline measurements very poor; probable error is plus or minus 15%. The last two were recorded directly with much greater accuracy. Immediately following these last two runs the thrust scale was re-calibrated, and

this value used.

Results:

The nozzle was designed to expand superheated steam from 300 to 15 lb. pressure, and the increasing efficiency with the higher chamber pressures indicates that the same ratio applies closely to the products of combustion as well as steam; also it suggests the possibility of even higher efficiencies at high pressures, since the designed P_c was not reached.

Among the nozzle materials tested, alumina (Al_2O_3) cast from thermit slag was the only one found satisfactory, and this material is extremely difficult to mould. Plastic refractories lacked the requisite resistance to erosion, graphite eroded and oxidized rather rapidly (a 1/4" nozzle doubled its diameter in five minutes at P_c of 30 lb), steel melted almost instantly. The materials tested were fireclay, alundum cement, graphite, steel, and alumina.

Preliminary tests were also made with a fuel-cooled regenerative motor, but bad leaks prevented complete results. Indications are that this type of cooling system works very well, but it is possible that at least a thin ceramic lining will be required.

To the writer's knowledge, these are the first rocket tests ever to be conducted using constant P_c (required for high nozzle efficiency) and with fully vaporized and properly mixed fuels. That this condition was obtained is indicated by the absence of flame at the nozzle mouth, as opposed to the long tongues usually seen.

An attempt is now being made to obtain permission to use oxygen instead of air in further tests. In the meantime the writer is building a flying rocket for the purpose of solving control and weight problems. It is to be of stainless-steel construction, with a refractory-lined, fuel-cooled motor, completely vaporized fuels, constant chamber pressure, and gyro control and parachute release. No flight attempts

will be made, however, until complete ground tests have eliminated all faults in design.

R.C.TRUAX

Midshipman, U.S.Navy.

Addenda to September Report

Since the submission of the report of the tests conducted last September, permission has been granted to use oxygen in place of air. Preliminary tests have been made on the motor designed for the flying rocket mentioned.

The motor is made of stainless steel, is three in. in diameter and about 14 in. overall, with the combustion chamber proper eight inches in length. The total weight, including a rather heavy experimental nozzle, is just over two pounds.

Under comparatively low pressures, a nozzle of alumina melted out in three minutes, and one lined with tungsten carbide (cast) cracked, but the pieces remaining showed no tendency to melt after ten seconds of operation (during which the metal backing burned out completely.) The experiments were conducted with a water jacket around the combustion chamber. Evaporative cooling proved adequate both for the combustion chamber and a stainless steel nozzle.

More rigorous tests are now underway on the metal nozzle. Pressure will be boosted to the designed 300 lb. and efficiency measurements taken. Eventually fuel will be substituted for the more convenient water in the jacket. Heat transfer calculations show the conduction from the chamber to be approximately 10,000 B.T.U./min.

Results on the current work will be reported as soon as completed, provided no official restrictions are forthcoming.

R. C. TRUAX

Experimental Rocket---Model 1939

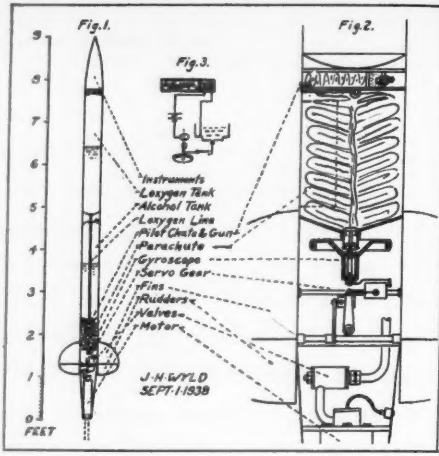
by

James H. Wyld

Garden City, N.Y.

Over a year ago Mr. Pendray outlined his "Specifications For a Rocket," and rocket men have been arguing ever since as to how closely his demands could be met by present rocket technique. It has been several years since an attempt has been made to evolve a rational rocket design on the basis of all available data; and such data has been accumulating steadily since 1935, when Mr. Africano's famous REP-Hirsch thesis on rocket design appeared. The author has ventured in the present article to present his conception of an experimental rocket----a Model 1939 rocket, approaching Mr. Pendray's "practical rocket" as nearly as possible, and under actual construction at the present time.

From Fig. 1 it will be seen that the rocket is a tail-drive type. gyro-stabilized, and carefully streamlined. It is 9 feet long and 5 inches in diameter, cylindrical, with a long ogival nose, a conical tail fairing, and four elliptical tail fins with movable rudders. It weighs about 17 pounds when empty and carries 18 pounds of propellant, made up of 11.25 pounds of loxygen and 6.75 pounds of ethyl alcohol. The fuel tanks are tandem, and are built up of light .025 inch sheet metal, silver-soldered at the seams. They are of nearly equal size, and filled slightly more than half-full. The upper tank, of Monel, contains the loxygen; this is fed through a central tube in the alcohol tank; the latter is of chrome-moly steel. The loxygen tank has a safety disk which ruptures under excessive pressure, and also a vent valve, which is closed immediately before firing; nitrogen pressure is then introduced into both tanks through fittings on the launching rack, till 250 lb per sq in is reached, and the rocket is then fired at once. Since the loxygen is thus well below its boiling point, boiling in the lines is much reduced; moreover, there is no pressure in the tanks until just before firing, which lessens the operating risk, and equal



Details of Mr. Wyld's New Rocket

pressure in both tanks is assured.

The valves are the usual Shesta type; the piping is 3/8 inch copper tubing. Orifices in the feed lines control the mixture proportioning. The rocket is designed to use the author's tubular regenerative motor(see Astronautics No.40; "Fuel as Coolant") but any other motor of similar size, weight, and thrust would be satisfactory. The selection of a suitable motor will depend on the results of the pending motor tests with Proving Stand No. 2.

The gyro-stabilizer is shown in Fig. 2. The 4-inch, 3/4 pound, ball-bearing gyroscope is suspended at its center of gravity on small gimbals attached to the bottom of the parachute case. It is brought up to 10,000 R.P.M. by an air-blast just before firing and coasts thereafter. The lower end of the gyro axle carries light valve rods operating tiny slide valves which control the motion of servo-cylinders sliding on stationary piston-rods. There are two such cylinders at right angles, each controlling one of the two rudder shafts through rudder levers; they are supplied with pressure through two flexible tubes leading to the gas-space in the alcohol tank. A small auxiliary tank (not shown) supplies pressure after firing has ceased and the main tank pressure is exhausted.

The fins are 1/4 inch plywood, fixed to studs attached to the rocket's shell; they are 6 inches wide and 8 inches long overall.

The parachute release mechanism is shown in Figs. 2 and 3. The parachute compartment is at the rear of the rocket, just ahead of the

gyro. This reduces the danger of fouling when the parachute is released, and brings the rocket down nose first, so that the meteorograph or other instrument in the nose is unaffected by the hot motor during the descent. The stabilizing gyro also acts as the parachute release, on the plan suggested by Pierce and Street (see Astronautics No.40.) as the gyro axis tilts and contacts an insulated ring, closing the circuit through an ignition fuse imbedded in the powder charge of the "paragun," a short tube containing a small pilot chute; the latter is thrown out sideways several feet, and pulls out the main chute through a door in the parachute case (shown in dotted lines.) A similar "gun" may be arranged to eject a smoke bomb to serve as a target for observers. As a precaution against premature release owing to "hunting" of the rocket, a safety switch is held open by tank pressure on a diaphragm, so that release can occur only after firing has ceased.

So much for the general construction of the new rocket. Now, how closely does it approach Mr. Pendray's idea?

In the matter of altitude, trajectory calculations by the author, Mr. Africano, and others, (for rockets similar in size, weight, power, and air-resistance to the one considered here), all indicate a height of around five miles; so it should be safe to predict an altitude of three miles at least, granting proper operation. A pay-load of two pounds is allowed for in the design. Two men could certainly fuel and fire the rocket (aside from observers at the altitude transits). If the motor, stabilizer, and parachute gear work properly, repair expenses would be negligible, while the fuel cost would be around five dollars per shot. A good gyro-stabilizer would almost certainly hold the flight to the true vertical within ten degrees. Transit observations would establish the height and landing position with good accuracy, and there is no difficulty about adding a small radio transmitter if desired. As for the velocity of fall, that is merely a matter of good parachute design, which would also ensure a safe landing.

However, we cannot at present undertake to design a rocket which

would come down within a short distance of its launching point; the complex, delayed-action parachute release, and the fast-acting meteorograph required, make this a nearly insoluble mechanical problem, though practical means for its solution may some day be found.

Theoretically, then, it appears possible to build a rocket capable of immediate application in meteorology and similar work. But there are many practical ifs and howevers involved. Though the proportions, weight, power, stabilizer proportions, and construction of the rocket have all been carefully and rationally worked out, the unusual and extreme operating conditions of rocketry make all deductions from conventional engineering data somewhat uncertain. Will the motor fire properly? Will the stabilizer exert sufficient force, yet not over-control or hunt? Will the parachute gear operate reliably and at the correct time? These questions can only be answered by actual test.

The gyroscope of the new rocket has been built and tested, the servo mechanism is now under construction, and work on the tanks will soon begin. It is hoped that the entire rocket will be completed during the year. Then, by the acid test of actual trial, it will be found whether the rocket is really approaching practicality or whether we must go on learning by one more mistake.

NEWS AND NOTES.

The annual meeting of the Society will be held Friday, April 21, 1939 at 8:00 P.M. at the United Engineering Societies Building, 29 West 39th Street, New York City.

FIRST TESTS OF PROVING STAND NO. 2.

The first field tests of Proving Stand No. 2 were described by Mr. John Shesta at the November meeting of the Society. Besides a technical account of the tests (which is given elsewhere in this issue) the meeting was edified by a recital of the hardships encountered by the hardy experimenters, who had to wheel the proving stand two miles by road and a quarter-mile over rough ground, pull a car out of a ditch

with the aid of stones lugged from a near-by well and a tow-rope composed of old auto chains, and live for two days on little but crackers and ham sandwiches.... Such are the sacrifices of Science!

HERMANN OBERTH---PIONEER OF ROCKETRY

At the same meeting Mr. James Wyld discussed the life and achievements of Hermann Oberth, famous Romanian rocket authority. Many people do not realize the importance of Oberth's ideas, for his famous book, "Die Rakete Zu Den Planetanraumen," was the inspiration for the early German rocket experiments of Valier, Opel, Nebel, and others, which in turn led to the later work of the American Rocket Society. Oberth was the originator of the modern liquid-fuel rocketry technique, and was also the inventor of the regenerative rocket motor which is so prominent in present experiments, as well as the use of gyroscopic steering gear. He also proposed the use of fuel pumps to reduce tank weight and worked out a theory of rocket efficiency which is probably the most complete yet developed. Many of these ideas, proposed by Oberth over fifteen years ago, are being confirmed today by the experiments of others.

THE REGENERATIVE MOTOR OPENS NEW POSSIBILITIES

The December meeting of the Society was devoted to a discussion of the second series of motor tests, run on December 10, and marked by the successful performance of the Society's regenerative rocket motor. Mr. John Shesta, Experimental Committee Chairman, discussed the method used in running the tests and the improvements made in the equipment since the October preliminary runs, and then announced the results attained in the new trials. The regenerative motor, Mr. Shesta pointed out, has proven to be a considerable advance over the motors tested in 1935, in thermal efficiency, exhaust velocity, and endurance, and if further tests confirm the results the biggest problem in rocketry, the development of an efficient and durable motor, will be solved.

Mr. James Wyld, inventor of the new motor, then discussed the methods used in designing it. Over a dozen preliminary designs were

worked out on paper before actually building the motor, and special attention was given to its cooling, using heat-transfer estimates derived from gas turbine tests. The design of the mixing ports was also carefully thought out to ensure proper mixing and proportioning. The satisfactory performance of the motor, said Mr. Wyld, is largely owing to the care expended on these preliminary estimates.

Mr. Nathan Carver writes to point out that the Wyld regenerative motor (see Page 3) gave only 11% efficiency when figured by the method used in the 1935 motor tests. The discrepancy, however, is explained by the fact that the present results were obtained from the slope of the fuel-weight curves, instead of averaging all the fuel originally put into the tank, much of which was simply blown out in incomplete combustion at the beginning and end of the run. The present figures refer to the steady conditions in the middle of the run, which represent the major part of the combustion and are of main importance in present experimental studies.

The Society announces with regret the resignation of two valued members from the Board of Directors---Mr. G. Edward Pendray, because of pressure of other dutues and Mr. James H. Wyld, because of the acceptance of a position in another city.

At a meeting of the Board of Directors on February 10, 1939, Mr. James Glazebrook and Mr. Roy E. Healy were elected to fill the vacancies on the Board.

ASTRONAUTICS, official publication of the American Rocket Society, is devoted to the scientific and engineering development of the rocket and its application to problems of research and technology. Published quarterly by the American Rocket Society, 50 Church St., New York City. Subscriptions with Associate Membership, $3 per year.